PB84-104603

Supplementary Guidelines for Lead Implementation Plans. Updated Projections for Motor Vehicle Lead Emissions

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Prepared for

Mar 83

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-450/2-83-002		PB84 104603

4. TITLE AND SUBTITLE	5. REPORT DATE
Supplementary Guidelines for Lead Implementation Plans -- Updated Projections for Automobile Lead Emissions	March 1983
	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Penny M. Carey	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
U.S. Environmental Protection Agency Office of Air, Noise, and Radiation Office of Mobile Sources Ann Arbor, MI 48105	11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
	Revision - Final
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This guidance is an update to Revised Section 4.3 (Projecting Automotive Lead Emissions), in the "Supplementary Guidelines for Lead Implementation Plans," U.S. EPA, EPA-450/2-78-038, Research Triangle Park, North Carolina, August 1978. The basic equation for projecting automotive lead emissions has been revised to incorporate the effect of the new EPA lead phase-down regulation, more recent on-road passenger car and light-duty truck fuel economy data, an estimate of increased dieselization of the light and heavy-duty fleet, the effect of misfueling, and more recent projections of the percent of vehicles from 1975 and beyond that require the use of nonleaded gasoline. Also discussed are current expectations regarding heavy-duty vehicle emission standards which affect use of leaded fuel.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Atmosphere contamination control Lead	State implementation plan National ambient air quality standard	13-B

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release unlimited	Unclassified	
	20. SECURITY CLASS *(This page)*	22. PRICE
	Unclassified	

EPA Form 2220-1 (9-73)

PB84-104603

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

Office of Mobile Sources
Ann Arbor Michigan 48105

EPA-450/2-83-002
March 1983

EPA

Air

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REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

EPA-450/2-83-002
March 1983

Supplementary Guidelines For Lead Implementation Plans

Updated Projections For Motor Vehicle Lead Emissions

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This report has been reviewed by the Office of Air Quality Planning and Standards, US EPA, and approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

INTRODUCTION

The following material serves as an update to Revised Section 4.3, (Projecting Automotive Lead Emissions), in the "Supplementary Guidelines for Lead Implementation Plans," U.S. EPA, EPA-450/2-78-038, Research Triangle Park, North Carolina, August 1978. This document provides updated projections for automotive lead emissions to be used by those agencies developing State Implementation Plans for lead.

This document changes the basic equation for projecting automotive lead emissions presented in Revised Section 4.3 of the Supplementary Guidelines. The equation has been revised to incorporate the effect of the new EPA lead phase-down regulation, more recent on-road passenger car and light-duty truck fuel economy data, an estimate of increased dieselization of the light and heavy-duty fleet, more recent projections of the percent of vehicles from 1975 and beyond that require the use of nonleaded gasoline and the effects of misfueling and discretionary fuel switching. Also discussed are current expectations regarding heavy-duty vehicle emission standards which affect use of leaded fuel.

The procedure herein should be used to project automotive lead emissions instead of the procedure given in Revised Section 4.3 of the Supplementary Guidelines.

Those agencies developing State Implementation Plans for lead should also note how the revision being made affects the EPA guideline, "Development of an Example Control Strategy for Lead" (EPA-450/2-79-002). Specifically affected are equations 2.3 (p. 14), 2.4 and 2.5 (p. 15) and the related discussion, which are based on the previous procedure. The new procedure should be used in lieu of that given on pp. 14 and 15 and related pages of the example control strategy for lead.

This document was prepared by the Office of Mobile Sources in response to the February 1983 request of the Office of Air Quality Planning and Standards. Further revisions will be made as needed as new information becomes available.

4.3 PROJECTING AUTOMOTIVE LEAD EMISSIONS

Lead emissions from mobile sources are calculated based on the percentage of burned lead exhausted at different speeds, the lead content of gasoline, vehicle fuel economy and the model year mix of vehicles on the road. The lead content of gasoline and the model year vehicle mix are a function of the calendar year of interest. Vehicle fuel economy is averaged for all vehicles of the same model year.

4.3.1 Lead Emissions from Automobiles

4.3.1.1 Individual Roadways - For any given year subsequent to 1974, the total population of automobiles on the road consists of vehicles using either leaded or "nonleaded" (i.e., required to contain less than 0.050 gram/gal. lead) gasoline or diesel fuel. Diesel fuel is assumed to contain quantities of lead that are insignificant compared to gasoline fuel; therefore, only emissions from gasoline-powered vehicles are considered. The emission rate from automotive sources from an individual roadway (line source) is calculated by the following equation:

$$e_{n,s} = \frac{a_s T}{C_s}\left[\left(Pb_{NL,n}\,(0.92) + Pb_{L,n}\,(0.08)(0.55)\right)\sum_{i=1975}^{n}\left(\frac{m_i F_{NL,i}}{E_{c,i}}\right)\right.$$

$$+\left(Pb_{L,n}(0.929) + Pb_{NL,n}(0.071)\right)\sum_{i=n-19}^{1974}\left(\frac{m_i F_{L,i}}{E_{c,i}}\right)$$

$$\left.+\left(Pb_{L,n}(0.725) + Pb_{NL,n}(0.275)\right)\sum_{i=1975}^{n}\left(\frac{m_i F_{L,i}}{E_{c,i}}\right)\right] \quad (1)$$

where:

$e_{n,s}$ = emission rate for calendar year n and speed s (g/road mile-day);

a_s = fraction of lead burned that is exhausted; for roadways where steady cruise driving is indicated (i.e., roadways that have a relatively constant speed), a_s is available from Figure 4.3-1 (nondimensional; expressed as a percentage in Figure 4.3-1); for roadway portions subject to full-throttle acceleration (0-60 mph) use a_s = 10.0 (i.e., 1000%); for roadways where cyclic driving is indicated (i.e., roadways that do not have steady speed) use a_s = 0.75 (i.e., 75%);

T = average daily traffic (vehicles/day);

C_s = speed-dependent fuel economy correction factor based on steady cruise or cyclic driving; available from Table 4.3-1 (nondimensional);

$Pb_{NL,n}$ = lead content of "nonleaded" gasoline in calendar year n from Table 4.3-2 (g/gal);

$Pb_{L,n}$ = average lead content of leaded gasoline in calendar year n from Table 4.3-2 (g/gal);

m_i = fraction of annual travel by model year i light-duty vehicles from Table 4.3-3 (nondimensional, expressed as a decimal);

$F_{NL,i}$ = fraction of the model year i light-duty vehicle fleet designed for use on nonleaded gasoline from Table 4.3-4 (nondimensional, expressed as a decimal);

$F_{L,i}$ = fraction of the model year i light-duty vehicle fleet designed for use on leaded gasoline from Table 4.3-4 (nondimensional, expressed as a decimal);

$E_{c,i}$ = city/highway combined on-road fuel economy for model year i from Table 4.3-9 (vehicle-road mile/gal.).

To calculate the emission rate in units of grams/meter-second, $e_{n,s}$ can be corrected by dividing by 1.39×10^8.

Referring to equation (1), the three terms within the brackets give the grams lead emitted per vehicle-road mile (g lead/vehicle-road mile) for calendar year n. The first term within the brackets gives the g lead/vehicle-road mile

emitted by light-duty catalyst-equipped vehicles whereas the second and third terms within the brackets collectively give the g lead/vehicle-road mile emitted by non-catalyst-equipped vehicles. It should be noted that since 1975 a small number of non-catalyst-equipped vehicles have been certified for use on nonleaded gasoline. Since these vehicles constitute such a small percentage of the total non-catalyst fleet, they will not be considered. Instead, it will be assumed that all non-catalyst-equipped vehicles can be operated on leaded gasoline. Further discussion of selected variables used in the equation follows.

Figure 4.3-2 compares steady cruise fuel economy and generalized cyclic driving fuel economy to vehicle speed. Figure 4.3-2 was generated using data from 1973, 1974 and 1975 model year vehicles. Using the cyclic driving fuel economy at 32.7 miles per hour as the basis for comparison (since this speed is the average speed for the EPA combined city/highway fuel economy), fuel economy correction factors (C_s) for both steady cruise and cyclic driving can be calculated at various speeds. These calculations have been made and are presented in Table 4.3-1. Table 4.3-1 should be used to interpolate C_s for those speeds not listed in Table 4.3-1. The fuel economy correction factor for cyclic driving should be used for roadways that do not have steady speed. (The determination of how much variation in speed constitutes

cyclic driving is judgmental. Questionable cases should be analyzed both ways.) Likewise, the fuel economy correction factor for steady cruise driving should be used if free-flow, steady speed driving is indicated (e.g., along a highway at a relatively constant speed). The correction factors for cyclic and steady cruise driving become similar at high speeds as the number of stops, accelerations and decelerations during cyclic driving decrease.

The fraction of annual travel by model year i light-duty vehicles (m_i) can be found in the last column of Table 4.3-3. Values for m_i in Table 4.3-3 are EPA's estimates of the national values. Local values should be used where available. The term, "m_i", accounts collectively for all light-duty vehicles - those using leaded, nonleaded, and diesel fuels - in a given model year. The travel weighting fractions were taken from the March 1981 EPA Report, "Compilation of Air Pollutant Emission Factors: Highway Mobile Sources" [EPA-460/3-81-005] and may be revised in the future. It should be noted that the travel weighting fractions in Table 4.3-3 reflect a January 1 evaluation date, in contrast to the July 1 evaluation date used in Revised Section 4.3.

The fractions of the model year i light-duty vehicle fleet using nonleaded and leaded gasoline, $F_{NL,i}$ and $F_{L,i}$,

respectively, are given in Table 4.3-4. Values for $F_{NL,i}$ and $F_{L,i}$ account for the increasing dieselization of the light-duty vehicle fleet. Diesel-powered vehicles are assumed to emit quantities of lead that are insignificant compared to gasoline-powered vehicles; therefore, sales fractions for diesel-powered vehicles are not included. Latest sales projections for diesel-powered vehicles were made by EPA based on data obtained from Jack Faucett Associates, "The Impact of Light-Duty Diesel Particulate Standards on the Level of Diesel Penetration in the Light-Duty Vehicle and Light-Duty Truck Markets" (January 1983), prepared under EPA contract. Estimates of the percentages of gasoline vehicles requiring leaded and nonleaded fuel were obtained from Energy and Environmental Analysis, Inc., "Documentation for the New Highway Fuel Consumption Model" (January 1982).

The term, "$m_i F_{NL,i}$" in equation (1), then, is the fraction of annual travel by model year i light-duty vehicles designed for use on nonleaded gasoline; "$m_i F_{L,i}$" is the fraction of annual travel by model year i light-duty vehicles designed for use on leaded gasoline.

An eight(8) percent misfueling rate for nonleaded gasoline-powered vehicles was incorporated into equation (1). Misfueling is defined as the use of leaded gasoline in vehicles certified for the use of nonleaded gasoline. This

misfueling rate was used in the March 1981 EPA Report, "Compilation of Air Pollutant Emission Factors: Highway Mobile Sources" [EPA-460/3-81-005] and may be revised in the future. The first term in equation (1) accounts for this eight(8) percent of nonleaded gasoline-powered vehicles which use leaded fuel even though use of nonleaded fuel in these vehicles is required to prevent poisoning of the catalyst and/or other effects of lead (e.g., combustion chamber deposits, EGR deterioration) that result in these vehicles not meeting the emission standards. An additional fraction, 0.55, is also included in the first term. This is an estimate of the fraction of lead burned that is exhausted from the catalyst of a misfueled, catalyst-equipped vehicle. This estimate was obtained from Schneider, Eric, W., "Detection of Leaded-Gasoline Usage in Catalyst-Equipped Vehicles: A Gamma-Ray Transmission Gauge for Measuring Catalytic Converter Lead Contamination", APCA Journal, Vol. 32, No. 5, May 1982. It should be considered a correction factor to a_s for catalyst-equipped vehicles using leaded fuel.

In addition to misfueling rates, discretionary fuel switching rates for leaded gasoline-powered vehicles were incorporated into equation (1). Discretionary fuel switching is the use of nonleaded gasoline in vehicles which normally operate on leaded fuel. The discretionary fuel switching rates were obtained from Energy and Environmental Analysis, Inc.,

"Assessment of Current and Projected Future Trends in Light-Duty Vehicle Fuel Switching" (June 1982) and are applicable to automobiles and light-duty trucks with a gross vehicle weight rating of less than 10,000 pounds. Discretionary fuel switching rates for pre-1975 model year vehicles designed for use on leaded fuel average 7.1 percent while rates for post-1974 model year vehicles average 27.5 percent. The effect of discretionary fuel switching for pre-1975 and post-1974 model year vehicles designed for use on leaded fuel has been incorporated into the second and third terms, respectively, in equation (1).

The city/highway combined on-road fuel economies, $E_{c,i}$, for model years 1970 to 1988 are given in Table 4.3-9. These fuel economies were obtained from Energy and Environmental Analysis, Inc., "The Highway Fuel Consumption Model - Eighth Quarterly Report" (July 1982). EPA fuel economies were discounted to on-road estimates by EEA with the use of technology-specific shortfall relations.

4.3.1.2 Area Source Automotive Emissions - Equation (1) can be modified to calculate automotive emissions as an area source rather than as specific line sources. The emission rate from automotive sources from an area source is calculated by the following equation:

$$e_{n,s} = \frac{V}{C_s}\left[\left(Pb_{NL,n}(0.92)(0.75) + Pb_{L,n}(0.08)(0.30)\right)\sum_{i=1975}^{n}\left(\frac{m_i F_{NL,i}}{E_{c,i}}\right)\right.$$

$$+\left(Pb_{L,n}(0.929)(0.75) + Pb_{NL,n}(0.071)(0.75)\right)\sum_{i=n-19}^{1974}\left(\frac{m_i F_{L,i}}{E_{c,i}}\right)$$

$$\left.+\left(Pb_{L,n}(0.725)(0.75) + Pb_{NL,n}(0.275)(0.75)\right)\sum_{i=1975}^{n}\left(\frac{m_i F_{L,i}}{E_{c,i}}\right)\right] \quad (2)$$

In equation (2), the term "T" was replaced by the term "V", the vehicle miles traveled in the area on a daily, monthly or greater time basis. When VMT data are used, the emission rate, $e_{n,s}$, will be expressed in grams per day, month, etc.

The computation of area emissions precludes the use of Figure 4.3-1 for determining the percentage of burned lead exhausted, a_s. Figure 4.3-1 is based primarily on tests of lead emissions from vehicles operating at steady speeds over short test periods. A value for a_s of 0.75 (i.e, 75 percent of the lead burned is exhausted) should be used for non-catalyst-equipped, gasoline-powered vehicles operating on leaded fuel when calculating automotive emissions as an area source rather than as specific line sources. The 0.75 value is based on tests which measured exhaust emissions under cyclic driving conditions. For gasoline-powered vehicles

with catalysts which are misfueled, a value for a_s of 0.30 should be used. The 0.30 value accounts for lead retention by the catalyst, the oil, the combustion chamber and the rest of the exhaust system*. The appropriate values for a_s have been included within the brackets in equation (2).

Finally, the speed dependent fuel economy correction factor, $C_{s,i}$, can be determined by either of two approaches. One approach is to base $C_{s,i}$ on the average vehicle speed for the area of concern. The average area vehicle speed should be a weighted average based on average speeds and VMT data for the various roadway classifications, such as limited access (greater than 50 mph), suburban roads (35 mph) and urban streets (25 mph or less). The other approach is to determine $C_{s,i}$ and area emissions for each roadway classification (and average speed) separately, and then total them. The latter approach is considered more accurate.

*For gasoline-powered vehicles with catalysts which are misfueled, 45 percent of the lead burned is retained by the catalyst and 25 percent of the lead burned is retained by the oil, the combustion chamber and the rest of the exhaust system; therefore 30 percent of the lead burned is exhausted (1.00-0.45-0.25 = 0.30).

4.3.2 Lead Emissions from Other Gasoline-Powered Vehicles

In addition to light-duty gasoline-powered vehicles, other vehicles to consider include motorcycles, light-duty gasoline-powered trucks and heavy-duty gasoline-powered trucks.

Motorcycles are assumed to emit quantities of lead that are insignificant compared to other gasoline-powered vehicles.

Light-duty gasoline-powered trucks have been separated into two categories. Light-duty gasoline-powered trucks I have a gross vehicle weight (GVW) rating of 6000 pounds or less. Light-duty gasoline-powered trucks II have a GVW rating of 6001 to 8500 pounds. The emission rates for each light-duty truck category are calculated using the same equations as for automobiles. The only revision is that the starting point for calculating emissions from nonleaded light-duty trucks II is 1979 rather than 1975. Values for the variables used in the equations are given in the following tables/figures:

Variable	LDT 1	LDT2
a_s	Figure 4.3-1	Figure 4.3-1
C_s	Table 4.3-1	Table 4.3-1
$Pb_{NL,n}$; $Pb_{L,n}$	Table 4.3-2	Table 4.3-2
m_i	Table 4.3-5	Table 4.3-7
$F_{NL,i}$; $F_{L,i}$	Table 4.3-6	Table 4.3-8
$E_{c,i}$	Table 4.3-9	Table 4.3-9

Values for a_s and C_s are the same as those for automobiles. In contrast, values for m_i, $F_{NL,i}$ $F_{L,i}$ and $E_{c,i}$ are different from those used for automobiles. Values for m_i in the last columns of Tables 4.3-5 and 4.3-7 are national values compiled by EPA in the March 1981 EPA Report, "Compilation of Air Pollutant Emission Factors: Highway Mobile Sources" [EPA-460/3-81-005] and may be revised in the future. Local values for m_i are preferable when available.

Heavy-duty gasoline-powered trucks are assumed to burn leaded gasoline until 1988. It is assumed that emission standards effective in 1988 will result in the use of nonleaded fuel in all heavy-duty gasoline-powered trucks. Also, their fuel economy for any calendar year is assumed to be equal to 5.0 miles/gal. Therefore, the emission rate for heavy-duty gasoline-powered trucks prior to 1988 is calculated by using the following modification of equation (1):

$$e_{n,s} = \frac{a_s T \, Pb_{L,n}}{5.0} \qquad (n < 1988) \qquad (3)$$

where T is the average daily traffic (heavy-duty gasoline trucks/day).

For 1988 and beyond, the following modification of equation (3) should be used:

$$e_{n,s} = \frac{a_s T}{5.0} \left[Pb_{L,n} \sum_{i=n-19}^{1987} m_i + Pb_{NL,n} \sum_{i=1988}^{n} m_i \right] \quad (n \geq 1988) \qquad (4)$$

Values for the variables used in equations (3) and (4) are given in the following tables/figures:

Variable	HDGT
a_s	Figure 4.3-1
C_s	Table 4.3-1
$Pb_{NL,n}$; $Pb_{L,n}$	Table 4.3-2
m_i	Table 4.3-10

The effect of discretionary fuel switching has not been incorporated in equations (3) and (4) due to the lack of data on the current fuel purchase behavior of owners of heavy-duty vehicles. Similarly, the effect of misfueling has not been incorporated in equation (4) since this would apply to heavy-duty vehicles not currently in production for which no data exist. As new estimates for heavy-duty fuel economy and new emission standards scenarios become available, equations (3) and (4) will be revised accordingly. Values for m_i may also be revised as new estimates become available.

Fleet sales fractions for heavy-duty gasoline-powered trucks I and II, projected to 1995, are given in Table 4.3-11. Heavy-duty gasoline-powered trucks I have a gross vehicle weight (GVW) rating of 8,501 to 26,000 pounds. Heavy-duty gasoline-powered trucks II have a GVW rating greater than 26,000 pounds. The fleet sales fractions are decreasing with model year, reflecting the increasing dieselization of the heavy-duty fleet. These estimated fleet sales fractions can be used when projecting T, the average daily traffic (heavy-duty gasoline trucks/day), for future years.

Equations (3) and (4) can be modified to calculate emissions as an area source rather than as specific line sources. The term "T" should be replaced by the term "V", the vehicle miles traveled by heavy-duty gasoline-powered trucks in the area on a daily, monthly or greater time basis. The fleet sales fractions in Table 4.3-11 can be similarly used to project area VMT for future years. When VMT data are used, the emission rate, $e_{n,s}$, will be expressed in grams per day, month, etc. Also, a_s, the fraction of burned lead exhausted, should be 0.75.

4.3.3 Example Calculation of Automobile Lead Emissions

Problem: For a roadway where steady cruise driving is indicated with a speed of 20 miles per hour and average daily

traffic of 28,000 vehicles, calculate the lead emission rate for the year 1988.

Solution: Use Equation (1):

$$e_{88,20} = \frac{a_{20}T}{C_{20}}\left[\left(Pb_{NL,88}(0.92) + Pb_{L,88}(0.08)(0.55)\right)\sum_{i=1975}^{1988}\left(\frac{m_i F_{NL,i}}{E_{c,i}}\right)\right.$$

$$+ \left(Pb_{L,88}(0.929) + Pb_{NL,88}(0.071)\right)\sum_{i=1969}^{1974}\left(\frac{m_i F_{L,i}}{E_{c,i}}\right)$$

$$\left. + \left(Pb_{L,88}(0.725) + Pb_{NL,88}(0.275)\right)\sum_{i=1975}^{1988}\left(\frac{m_i F_{L,i}}{E_{c,i}}\right)\right]$$

From Figure 4.3-1, for a cruise speed of 20 mph, approximately 15.25 percent of the lead being burned is emitted. Therefore, $a_{20} = 0.153$.

The average daily traffic, T, is given as 28,000 vehicles/day. From Table 4.3-1, since steady cruise driving is indicated, the speed-dependent fuel economy correction factor for a speed of 20 mph, $C_{20} = 1.153$.

From Table 4.3-2, the lead content of leaded gasoline in 1988 is 1.1 grams/gal., and the lead content of nonleaded gasoline is 0.014 gram/gal.

The summations,

$$\sum_{i=1975}^{1988} \left(\frac{m_i F_{NL,i}}{E_{c,i}}\right), \quad \sum_{i=1969}^{1974} \left(\frac{m_i F_{L,i}}{E_{c,i}}\right) \quad \text{and} \quad \sum_{i=1975}^{1988} \left(\frac{m_i F_{L,i}}{E_{c,i}}\right)$$

for vehicles burning nonleaded and leaded gasoline, respectively, must now be calculated. First, the fraction of annual travel, m_i, for each model year is determined by setting the fraction for 1 year old vehicles (Table 4.3-3) at the calendar year, n, for which lead emissions are being estimated. For this example, n = 1988, therefore, m_{1988} = 0.031 (vehicle age=1). The term, m_i, accounts collectively for all vehicles - leaded, nonleaded, and diesel - of a given model year; its use is illustrated in Table 4.3-12. Table 4.3-12 also presents the appropriate values for $F_{NL,i}$ and $F_{L,i}$ from Table 4.3-4, and $E_{c,i}$ from Table 4.3-9.

The summations for nonleaded and leaded gasoline can now be completed as shown in Table 4.3-12. As that table indicates:

$$\sum_{i=1975}^{1988} \left(\frac{m_i F_{NL,i}}{E_{c,i}} \right) = 0.0381 \text{/vehicle-road miles/gal.}$$

$$\sum_{i=1969}^{1974} \left(\frac{m_i F_{L,i}}{E_{c,i}} \right) = 0.0022 \text{/vehicle-road miles/gal.}$$

and,

$$\sum_{i=1975}^{1988} \left(\frac{m_i F_{L,i}}{E_{c,i}} \right) = 0.0012 \text{/vehicle-road miles/gal.}$$

Substituting the above results into Equation (1), we obtain:

$$e_{88,20} = \frac{0.153 \times 28 \times 10^3 \text{ vehicles/day}}{1.153} \times \left[\left((0.014 \text{g/gal} \times 0.02 + 1.1 \text{g/gal} \times 0.08 \times 0.55) \times \frac{0.0381}{\text{veh-road mi/gal}} \right) + \left((1.1 \text{g/gal} \times 0.929 + 0.014 \text{g/gal} \times 0.071) \times \frac{0.0022}{\text{veh-road mi/gal}} \right) + \left((1.1 \text{g/gal} \times 0.0725 + 0.014 \text{g/gal} \times 0.275) \times \frac{0.0012}{\text{veh-road mi/gal}} \right) \right]$$

$$= 17.39 \text{ g/road-mile-day}$$

In units of g/m-sec, this becomes:

$$e_{88,20} = \frac{17.39}{1.39 \times 10^8} = 1.25 \times 10^{-7} \text{ g/mi-sec.}$$

Figure 4.3-1

PERCENTAGE OF BURNED LEAD EXHAUSTED

vs.

VEHICLE CRUISE SPEED

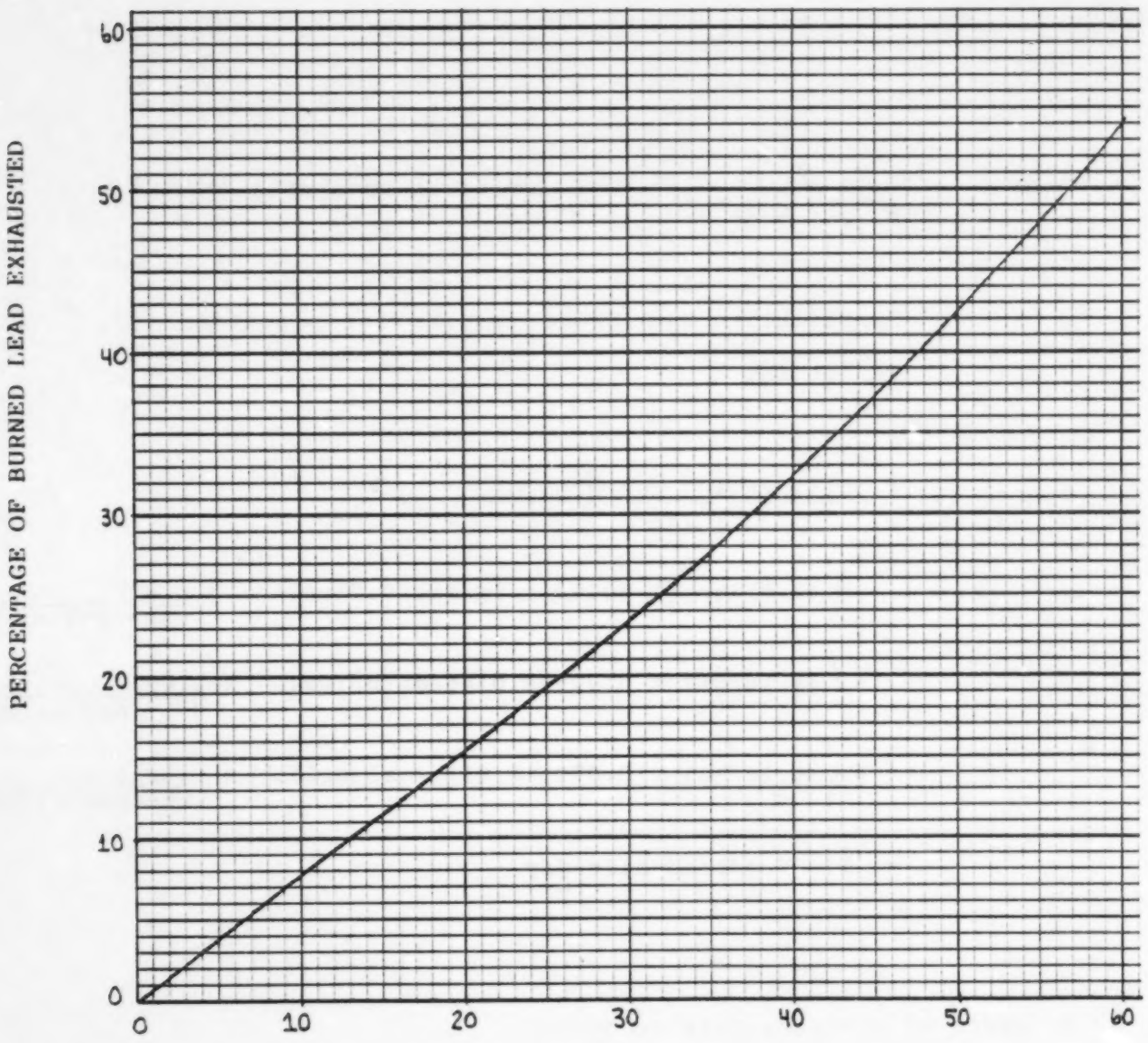
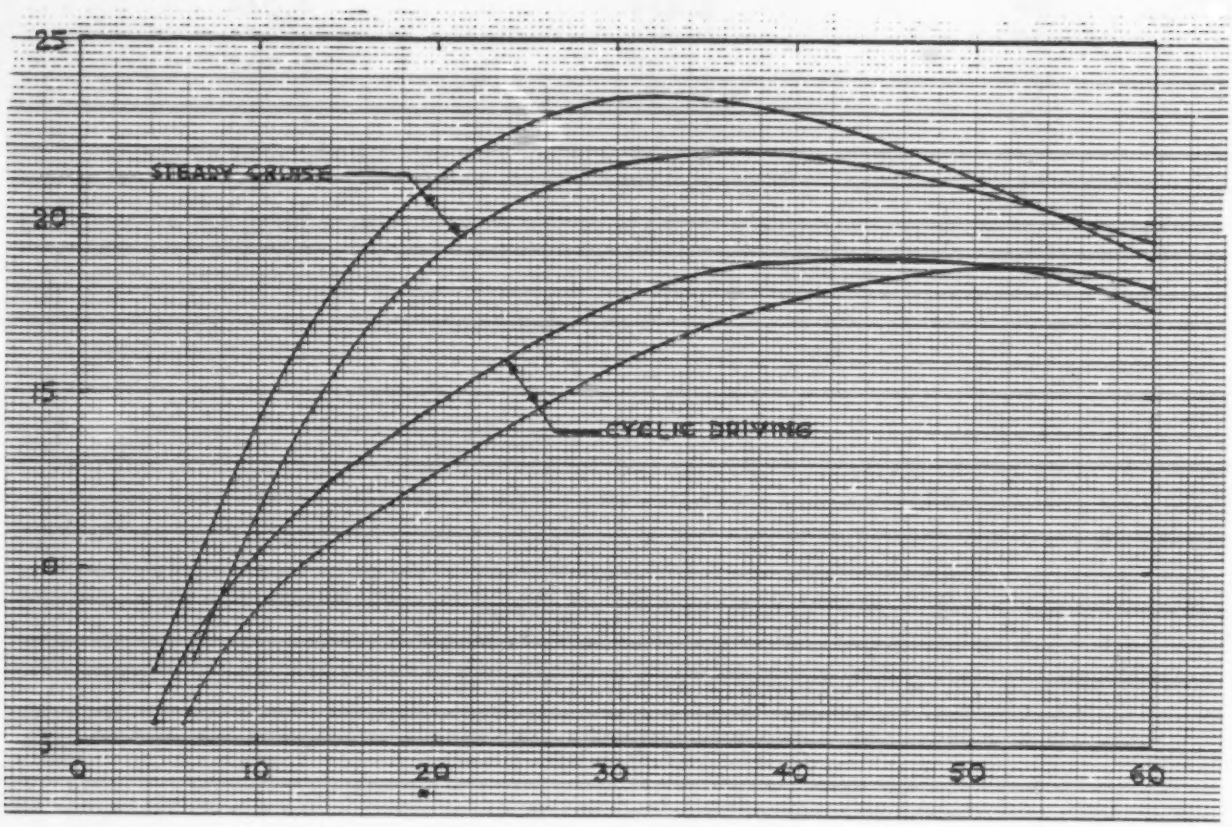


Figure 4.3-2

FUEL ECONOMY AT VARIOUS SPEEDS*



* Passenger Car Fuel Economy: EPA and Road, September 1980, [EPA-460/3-80-010].

Table 4.3-1

FUEL ECONOMY CORRECTION FACTORS AT VARIOUS SPEEDS, C_s
(Normalized to 32.7 miles/hour-cyclic driving)

Speed (mph)	C_s Cyclic Driving	C_s Steady Cruise
5	0.323	0.467
10	0.553	0.709
15	0.692	0.997
20	0.790	1.153
25	0.885	1.248
30	0.963	1.294
32.7	1.000	1.303
35	1.022	1.303
40	1.053	1.288
45	1.073	1.256
50	1.078	1.210
55	1.063	1.159
60	1.023	1.104

Table 4.3-2

LEAD CONTENT OF GASOLINE

Year	Leaded Gasoline* (g/gal)	Nonleaded Gasoline (g/gal)
1974	1.79	-
1975	1.82	0.014
1976	2.02	0.014
1977	2.03	0.014
1978	1.94	0.014
1979	1.85	0.014
1980	1.38	0.014
1981	1.15	0.014
1982	1.24	0.014
1983	1.14	0.014
1984	1.1	0.014
1985	1.1	0.014
1986	1.1	0.014
1987	1.1	0.014
1988	1.1	0.014
1989	1.1	0.014
1990	1.1	0.014

*1974-1982: Lead content based upon data submitted to EPA on historical sales data for leaded gasoline and data indicating the actual pooled average lead content. The value for nonleaded gasoline is based on recent MVMA fuel surveys.

1983-1990: Lead content based upon requirements for average lead content of leaded gasoline. During the first half of 1983, small refineries were subject to a pooled average lead standard.

Table 4.3-3

TRAVEL WEIGHTING FACTOR CALCULATION*

Light-Duty Vehicles

Vehicle Age	(a) Annual Fraction Total Registration	(b) Mileage Accumulation Rate	(a)(b)	[(a)(b)/(SUM)] Fraction of Annual LDV Travel by Model Year, m_i
1	0.024	14400	345.6	0.031
2	0.101	14275	1441.8	0.131
3	0.092	13775	1267.3	0.115
4	0.071	13250	940.8	0.085
5	0.092	12675	1166.1	0.106
6	0.103	12175	1254.0	0.114
7	0.089	11650	1036.9	0.094
8	0.071	11075	786.3	0.071
9	0.066	10575	697.9	0.063
10	0.059	10050	592.9	0.054
11	0.048	9475	454.8	0.041
12	0.035	8975	314.1	0.028
13	0.030	8450	253.5	0.023
14	0.023	7875	181.1	0.016
15	0.015	7375	110.6	0.010
16	0.010	6850	68.5	0.006
17	0.005	6275	31.4	0.003
18	0.003	5775	17.3	0.002
19	0.002	5275	10.6	0.001
20+	0.015	4750	71.3	0.006
		SUM:	11042.8	

*Compilation of Air Pollutant Emission Factors: Highway Mobile Sources, March 1981, [EPA-460/3-81-005]. The travel weighting fractions reflect a January 1 evaluation date.

Table 4.3-4

FLEET SALES FRACTIONS

Light-Duty Gasoline-Powered Vehicles

Model Years	Nonleaded Gasoline Fraction of LDV Fleet, $F_{NL,i}$*	Leaded Gasoline Fraction of LDV Fleet, $F_{L,i}$*
Pre-1975	0.000	1.000
1975	0.873	0.127
1976	0.868	0.132
1977	0.843	0.157
1978	0.844	0.126
1979	0.867	0.093
1980	0.950	0.000
1981	0.939	0.000
1982	0.954	0.000
1983	0.947	0.000
1984	0.940	0.000
1985	0.934	0.000
1986	0.927	0.000
1987	0.920	0.000
1988	0.910	0.000

WHERE:

$F_{NL,i}$ = Estimated fraction of the LDV model year fleet which use nonleaded gasoline.

$F_{L,i}$ = Estimated fraction of the LDV model year fleet which use leaded gasoline.

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*Diesel and gasoline sales projections were made by EPA based on data obtained from Jack Faucett Associates, "The Impact of Light-Duty Diesel Particulate Standards on the Level of Diesel Penetration in the Light-Duty Vehicle and Light-Duty Truck Markets", January 1983.

Percentages of gasoline vehicles requiring leaded and nonleaded fuel obtained from Energy and Environmental Analysis, Inc. "Documentation for the New Highway Fuel Consumption Model", January 1982.

Table 4.3-5

TRAVEL WEIGHTING FACTOR CALCULATION*

Light-Duty Trucks I**

Vehicle Age	(a) Fraction Total Registration	(b) Annual Mileage Accumulation Rate	(a)(b)	[(a)(b)/(SUM)] Fraction of Annual LDT1 Travel by Model Year, m_i
1	0.032	15600	499.2	0.055
2	0.094	15200	1428.8	0.157
3	0.085	13625	1158.1	0.127
4	0.061	12175	742.7	0.081
5	0.091	10925	994.2	0.109
6	0.099	9925	982.6	0.108
7	0.076	9200	699.2	0.077
8	0.060	8450	507.0	0.056
9	0.044	7875	346.5	0.038
10	0.048	7375	354.0	0.039
11	0.046	6900	317.4	0.035
12	0.033	6500	214.5	0.024
13	0.035	6125	214.4	0.023
14	0.033	5800	191.4	0.021
15	0.026	5425	141.1	0.015
16	0.021	5150	108.2	0.012
17	0.015	4925	73.9	0.008
18	0.011	4625	50.9	0.006
19	0.010	4400	44.0	0.005
20+	0.013	4400	57.2	0.006
		SUM:	9125.3	

*Compilation of Air Pollutant Emission Factors: Highway Mobile Sources, March 1981, [EPA-460/3-81-005]. The travel weighting fractions reflect a January 1 evaluation date.

**Light-duty trucks I have a gross vehicle weight (GVW) rating of 6000 pounds or less.

Table 4.3-6

FLEET SALES FRACTIONS

Light-Duty Gasoline-Powered Trucks I

Model Years	Nonleaded Gasoline Fraction of LDT1 Fleet, $F_{NL,i}$*	Leaded Gasoline Fraction of LDT1Fleet, $F_{L,i}$*
Pre-1975	0.000	1.000
1975	0.812	0.188
1976	0.912	0.088
1977	0.962	0.038
1978	0.968	0.027
1979	0.957	0.032
1980	0.956	0.023
1981	0.968	0.000
1982	0.958	0.000
1983	0.947	0.000
1984	0.931	0.000
1985	0.915	0.000
1986	0.905	0.000
1987	0.889	0.000
1988	0.873	0.000

WHERE:

$F_{NL,i}$ = Estimated fraction of the LDT1 model year fleet which use nonleaded gasoline.

$F_{L,i}$ = Estimated fraction of the LDT1 model year fleet which use leaded gasoline.

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*Diesel and gasoline sales projections were made by EPA based on data obtained from Jack Faucett Associates, "The Impact of Light-Duty Diesel Particulate Standards on the Level of Diesel Penetration in the Light-Duty Vehicle and Light-Duty Truck Markets", January 1983.

Percentages of gasoline vehicles requiring leaded and nonleaded fuel obtained from Energy and Environmental Analysis, Inc. "Documentation for the New Highway Fuel Consumption Model", January 1982.

Table 4.3-7

TRAVEL WEIGHTING FACTOR CALCULATION*

Light-Duty Trucks II**

Vehicle Age	(a) Fraction Total Registration	(b) Annual Mileage Accumulation Rate	(a)(b)	[(a)(b)/(SUM)] Fraction of Annual LDT2 Travel by Model Year, m_i
1	0.082	15800	1295.6	0.125
2	0.207	15400	3187.8	0.307
3	0.155	13800	2139.0	0.206
4	0.097	12300	1193.1	0.115
5	0.057	11125	634.1	0.061
6	0.056	10100	565.6	0.054
7	0.039	9300	362.7	0.035
8	0.030	8550	256.5	0.025
9	0.023	7975	183.4	0.018
10	0.020	7475	149.5	0.014
11	0.017	6975	118.6	0.011
12	0.011	6525	71.8	0.007
13	0.010	6225	62.3	0.006
14	0.008	5875	47.0	0.005
15	0.005	5425	27.1	0.003
16	0.006	5175	31.1	0.003
17	0.004	5000	20.0	0.002
18	0.003	4625	13.9	0.001
19	0.003	4400	13.2	0.001
20+	0.004	4400	17.6	0.002
		SUM:	10389.9	

*Compilation of Air Pollutant Emission Factors: Highway Mobile Sources, March 1981, [EPA-460/3-81-005]. The travel weighting fractions reflect a January 1 evaluation date.

**Light-duty trucks II have a gross vehicle weight (GVW) rating of 6001 to 8500 pounds.

Table 4.3-8

FLEET SALES FRACTIONS

Light-Duty Gasoline-Powered Trucks II

Model Years	Nonleaded Gasoline Fraction of LDT2 Fleet, $F_{NL,i}$*	Leaded Gasoline Fraction of LDT2 Fleet, $F_{L,i}$*
Pre-1975	0.000	1.000
1975	0.000	1.000
1976	0.000	1.000
1977	0.000	1.000
1978	0.000	0.988
1979	0.975	0.000
1980	0.950	0.000
1981	0.925	0.000
1982	0.901	0.000
1983	0.876	0.000
1984	0.838	0.000
1985	0.801	0.000
1986	0.776	0.000
1987	0.739	0.000
1988	0.702	0.000

WHERE:

$F_{NL,i}$ = Estimated fraction of the LDT2 model year fleet which use nonleaded gasoline.

$F_{L,i}$ = Estimated fraction of the LDT2 model year fleet which use leaded gasoline.

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*Diesel and gasoline sales projections were made by EPA based on data obtained from Jack Faucett Associates, "The Impact of Light-Duty Diesel Particulate Standards on the Level of Diesel Penetration in the Light-Duty Vehicle and Light-Duty Truck Markets", January 1983.

Percentages of gasoline vehicles requiring leaded and nonleaded fuel obtained from Energy and Environmental Analysis, Inc., "Documentation for the New Highway Fuel Consumption Model", January 1982.

Table 4.3-9

CITY/HIGHWAY COMBINED ON-ROAD FUEL ECONOMY*
(miles/gallon)

	Fuel Economy, $E_{c,i}$		
Model Year	LDV	LDT1	LDT2
Pre-1970	13.9	10.6	7.9
1970	13.9	10.6	7.9
1971	13.2	10.4	7.7
1972	13.1	10.2	7.4
1973	12.9	9.9	7.0
1974	12.6	9.6	6.9
1975	13.9	12.0	8.8
1976	14.9	12.6	9.7
1977	15.6	13.8	9.4
1978	16.7	14.3	9.6
1979	18.5	15.2	9.8
1980	19.6	16.3	11.5
1981	21.8	18.1	13.3
1982	23.3	18.4	13.8
1983	24.6	18.9	14.3
1984	26.0	19.5	14.9
1985	27.4	20.2	15.4
1986	28.8	21.1	16.0
1987	30.2	22.0	16.6
1988	31.6	22.9	17.2

*Fuel economies for model years 1980-1988 were obtained from Energy and Environmental Analysis, Inc., "The Highway Fuel Consumption Model - Eighth Quarterly Report" (U.S. DOE Contract Number DE-AC01-79PE-70032, Task No. 13, July 1, 1982). Fuel economies for model years 1970-1979 were obtained from Robert Dulla, EEA.

Table 4.3-10

TRAVEL WEIGHTING FACTOR CALCULATION*

Heavy-Duty Gasoline-Powered Trucks

Vehicle Age	(a) Fraction Total Registration	(b) Annual Mileage Accumulation Rate	(a)(b)	[(a)(b)/(SUM)] Fraction of Annual HDGT Travel by Model Year, m_i
1	0.0	0	0.0	0.000
2	0.114	21000	2394.0	0.203
3	0.097	18900	1833.3	0.155
4	0.073	17200	1255.6	0.106
5	0.086	15500	1333.0	0.113
6	0.088	14100	1240.8	0.105
7	0.070	12600	882.0	0.075
8	0.053	11300	598.9	0.051
9	0.041	10300	422.3	0.036
10	0.044	9400	413.6	0.035
11	0.040	8600	344.0	0.029
12	0.031	8000	248.0	0.021
13	0.030	7300	219.0	0.019
14	0.026	6700	174.2	0.015
15	0.021	6300	132.3	0.011
16	0.018	5900	106.2	0.009
17	0.013	5500	71.5	0.006
18	0.009	5200	46.8	0.004
19	0.008	5000	40.0	0.003
20+	0.010	5000	50.0	0.004
		SUM:	11805.5	

*Compilation of Air Pollutant Emission Factors: Highway Mobile Sources, March 1981, [EPA-460/3-81-005]. The travel weighting fractions reflect a January 1 evaluation date.

**Heavy-duty trucks have a gross vehicle weight (GVW) rating greater than 8,501 pounds.

Table 4.3-11

FLEET SALES FRACTIONS
Heavy-Duty Gasoline-Powered Trucks I and II*

Model Years	Gasoline Fraction of HDT1 Fleet**	Gasoline Fraction of HDT2 Fleet**
Pre-1977	0.982	0.136
1977	0.970	0.108
1978	0.968	0.111
1979	0.959	0.101
1980	0.950	0.092
1981	0.910	0.082
1982	0.870	0.072
1983	0.813	0.063
1984	0.755	0.053
1985	0.698	0.043
1986	0.681	0.040
1987	0.665	0.038
1988	0.648	0.035
1989	0.632	0.033
1990	0.615	0.030
1991	0.598	0.027
1992	0.582	0.025
1993	0.565	0.022
1994	0.549	0.020
1995	0.532	0.017

*Heavy-duty trucks I have a gross vehicle weight (GVW) rating of 8,501 to 26,000 pounds. Heavy-duty trucks II have a gross vehicle weight (GVW) rating greater than 26,000 pounds.

**The estimated fractions of the HDT1 and HDT2 model year fleets which are gasoline-powered are based on Data Resources Inc. sales projections for heavy-duty diesel vehicles, U.S. Long Term Review, Summer 1982.

Table 4.3-12

EXAMPLE CALCULATIONS

Light-Duty Gasoline Vehicle Lead
Emission Rate for the Year 1988

Model Year	Age	m_i	$F_{NL,i}$	$F_{L,i}$	$E_{c,i}$	(1975-1988) $\left(\frac{m_i F_{NL,i}}{E_{c,i}}\right)$	(1969-1974) $\left(\frac{m_i F_{L,i}}{E_{c,i}}\right)$	(1975-1988) $\left(\frac{m_i F_{L,i}}{E_{c,i}}\right)$
1988	1	0.031	0.910	-	31.6	0.0009		-
1987	2	0.131	0.920	-	30.2	0.0040		-
1986	3	0.115	0.927	-	28.8	0.0037		-
1985	4	0.085	0.934	-	27.4	0.0029		-
1984	5	0.106	0.940	-	26.0	0.0038		-
1983	6	0.114	0.947	-	24.6	0.0044		-
1982	7	0.094	0.954	-	23.3	0.0038		-
1981	8	0.071	0.939	-	21.8	0.0031		-
1980	9	0.063	0.950	-	19.6	0.0031		-
1979	10	0.054	0.867	0.093	18.5	0.0025		0.0003
1978	11	0.041	0.844	0.126	16.7	0.0021		0.0003
1977	12	0.028	0.843	0.157	15.6	0.0015		0.0003
1976	13	0.023	0.868	0.132	14.9	0.0013		0.0002
1975	14	0.016	0.873	0.127	13.9	0.0010		0.0001
1974	15	0.010	-	1.000	12.6	-	0.0008	
1973	16	0.006	-	1.000	12.9	-	0.0005	
1972	17	0.003	-	1.000	13.1	-	0.0002	
1971	18	0.002	-	1.000	13.2	-	0.0002	
1970	19	0.001	-	1.000	13.9	-	0.0001	
pre-1970	20+	0.006	-	1.000	13.9	-	0.0004	
						0.0381	0.0022	0.0012